THE DEPENDENT FLUCTUATION OF POLISHED SURFACE

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Polishing is one of very old processing techniques, which are used by mankind from ancient time. But, it is still exceedingly important technique, because it is used for ultra-precise processing to get the smoothest surface today. Actually, a finished surface of silicon wafer which is basic materials of LSI is accomplished by applying this technique.[1,2]

It is an important problem to know how the surface changes during the polishing process. A schematic machine structure of float polishing is shown in Fig. 1.[1,2] A characteristic point of this machine is no direct contact between a polished substance (sample) and the machine. There is a space between diamond-turned surface (see Fig. 1) and the polished substance. The space is filled with polishing fluid which is pure water containing many polishing particles. The polished substance is turned round the center axis of machine, and also turned round the center axis of sample holder. Therefore the surface of polished substance is hit by particles from every direction in the polishing fluid. The polishing particles which have enough hardness to sharpen a material are contained in the polishing liquid. When the polishing particle hits the surface of substance, some parts of polished surface are taken off. (The number of particle which is taken off depends on the momentum of polishing particles.) Finally, we get the smooth material surface, which has much less fluctuation.

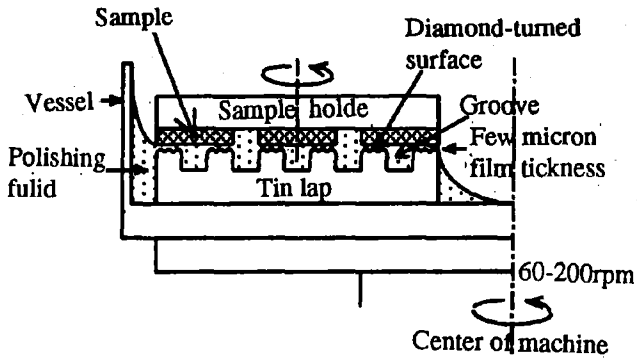

Fig. 1 Schematic structure of float polishing machine.

The basic mechanism of polishing is that the polishing particle takes off some particles at the surface when it strikes.

We assume that the polished substance is constituted of many particles which occupy the lattice points of a square lattice and a cubic lattice. It is assumed that the polishing particles strike a particle at a lattice point from the left for the sake of simplicity. A rough surface of substance is prepared which is made by using random numbers of Gaussian distribution in the beginning. A periodic boundary condition is used for the horizontal direction. When the polishing particle hits a lattice point of substance, a part of constituting particles in substance is removed from the main body of substance. The number of particles taken off is assumed to be proportional to the momentum of polishing particle, and we represent the magnitude of the momentum of polishing particle by the number of particles, k, which is taken off from the surface. We suppose that the particle number is kept to be constant during a simulation.

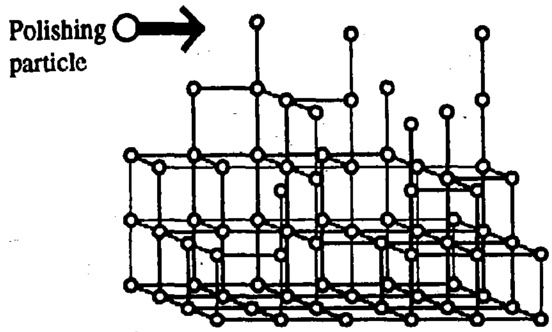

Fig. 2 Apolishing model on the cubic latice. The roughness of surface of material is produced according to Gaussian distribution. The direction of polishing particles is fixed.

The time, t, is increased by one when the polishing particle strikes at a lattice point. We consider that the polishing particle can hardly run into the deep groove. The probability that the polishing particle strikes a point of surface is inversely proportional to $(\text{height})^4$, and the height is measured from the lowest groove.

The fluctuation σ of the surface is calculated by the following expression

$$\sigma = \sqrt{\overline{\left(h-\bar{h}\right)^2}},$$

where h is the height of surface from the bottom of material, $\bar{h}$ is an average of the height.

The number of particles taken off by a strike of polishing particle is taken from two to fifty on three-dimensional cubic lattice of $50 \times 50 \times 140$ in this simulation. A result provided by this simulation is shown in Fig. 3. The vertical axis is the fluctuation σ, and the horizontal axis is the time t. We draw the curves for k from two to ten. The data shown in Fig. 3 are averaged over 200 times of simulations.

We obtain the following results from Fig. 3. We can find several characters in real polishing prosess from these results.

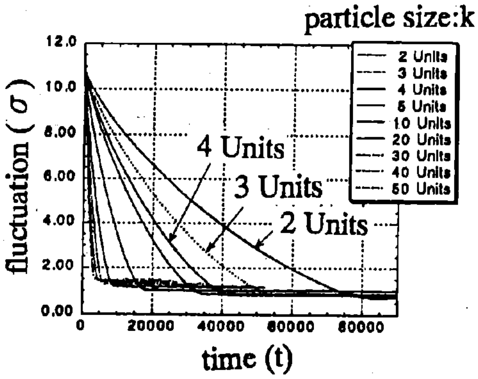

Fig. 3 The fluctuation σ versus the time.

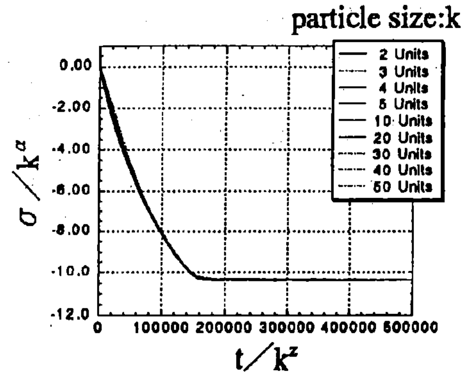

Fig. 4 After scaling collapse. σ'/k^{α} versus t/k^z. Where $\alpha = -0.025$, and $z = -0.98$.

We check scaling collapse of the fluctuation of rough surface. In Figure 4, we used $\alpha = -0.025$, and $z = -0.98$. The data collapse for every line is satisfied.

We have proposed the simple simulation for the float polishing process. It has been formed that the scaling function[3] for the fluctuation is expressed by

$$\sigma = -k^{\alpha} f\left(\frac{t}{k^z}\right) + \overline{\sigma_0}, \qquad \text{where } f(x) = \begin{cases} x & \text{for} \quad x \ll 80000 \\ const & \text{for} \quad x \gg 80000 \end{cases},$$

and $\alpha = -0.025$ and $z = -0.98$ ($\overline{\sigma_0} = 10.814$). We get the relation $\alpha + z \approx -1.00$. And we have already gotten the relation for the square lattice, which is $\alpha + z = -0.038 - 0.88 \approx -0.96$. We can say that these relations are nearly same. These results are different from the general relation $\alpha + z = 2$, which is well known for the KPZ equation.[4] Our scaling parameter is not the sample width l, but k which is proportional to the momentum of the polishing particle.

REFERENCE

1. Y. Namba, Technical Digest at the Topical Meeting on the Science of Polishing, OSA, TuB-A2(1984)
2. S. F. Soares, D. R. Baselt, J. P. Black, K. C. Jungling, and W. K. Stowell, Applied Optics 33, 89(1994)
3. M. Kardar, G. Parisi and Y.-C. Zhang, Phys.Rev. Lett. 56, 889-892(1986)
4. T. Vicsek and F. Family, Phys.Rev. Lett. 52, 1669(1984)